325 MHz IQ Modulator

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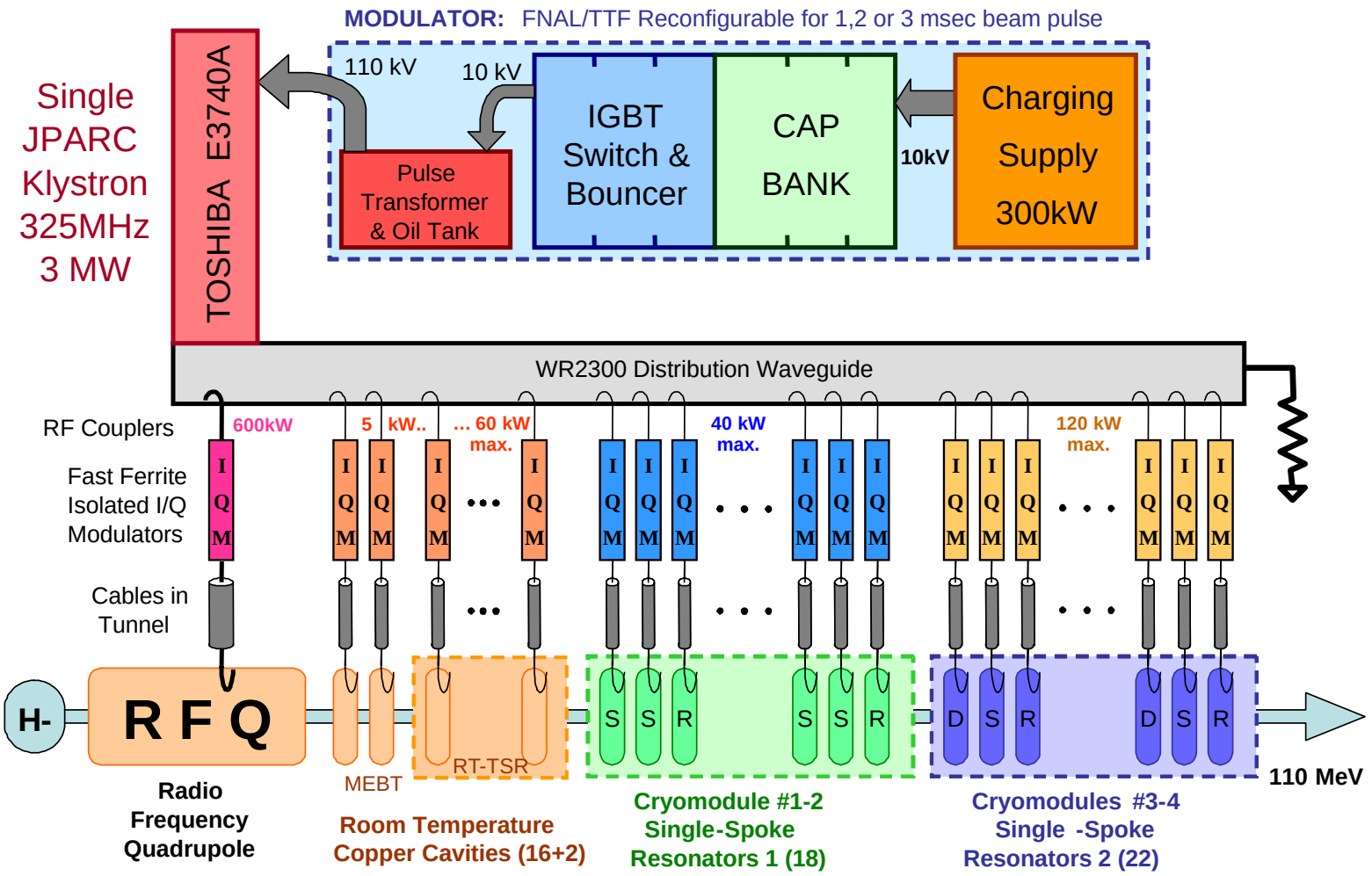
Fermilab Accelerator Advisory Committee
May 10th – 12th , 2006

Outline

- **IQ Modulator**
- **Circulator (status and plan)**
- **Fast Phase Shifter (status and plan)**
- **Hybrid (status and plan)**
- **Recent High Power Test Results**
- **Conclusions**

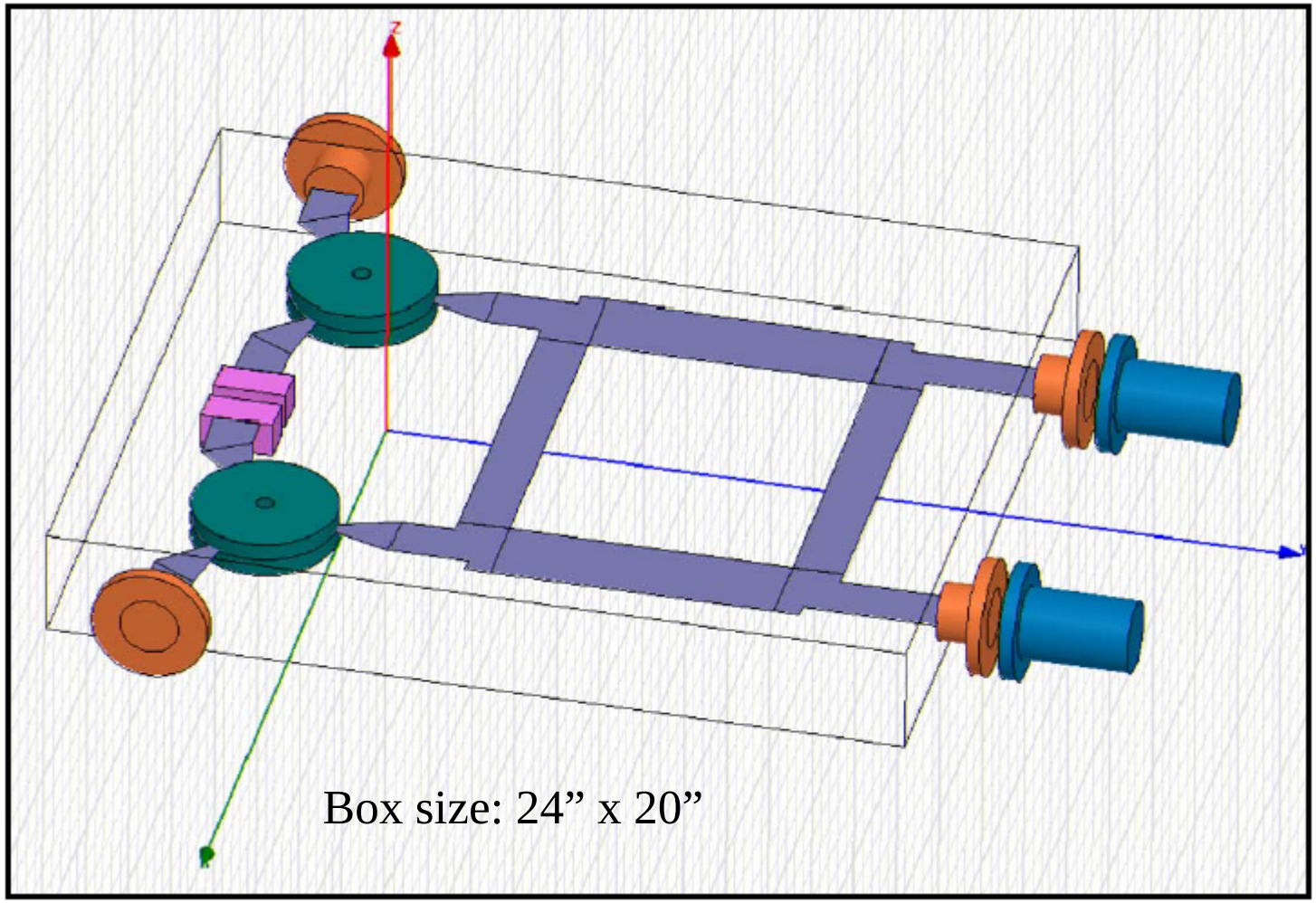
325 MHz RF Distribution System



IQ Modulator (Function)

- **The entire front-end linac up to 90 MeV is powered by a single 2.5 MW klystron.**
- **RF power is carried by a single WR 2300 waveguide alongside the beam line and partially extracted by a waveguide-coax coupler at the location of each RF structure.**
- **IQ modulators are used to control phase and amplitude of the input power for each RF structure.**
- **Circulator + hybrid + ferrite phase shifters**

IQ Modulator



IQ Modulator (Specification)

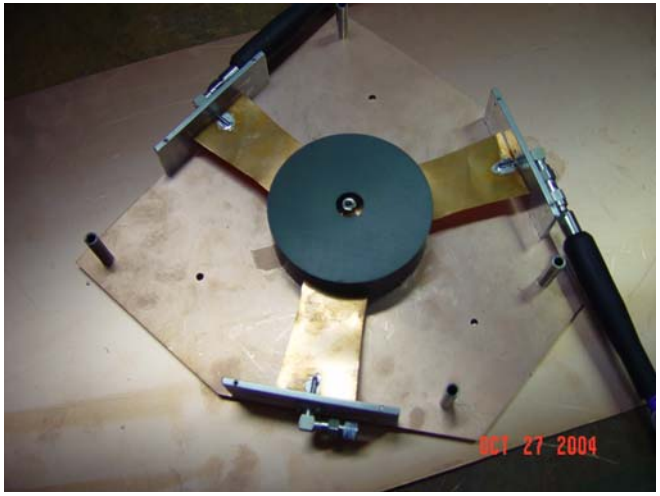
- **Peak Power**
  - 40 kW ~ 120 kW
  - 275 kW (for each drive loop of RFQ)
- **Tuning Range**
  - Phase: +/- 45 degree
  - Amplitude: +/- 1.5 db
- **Phase Tuner Slew Rate**
  - 1 degree/1μsec

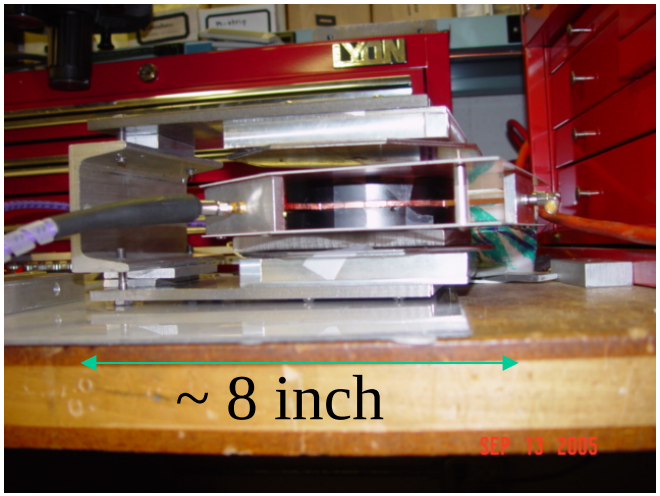
IQ Modulator (R&D Plan, 2005)

- **Design and make individual circulator, hybrid and fast ferrite phase shifter.**
- **Power test them separately, identify problems and modify design.**
- **Integrate them and power test.**

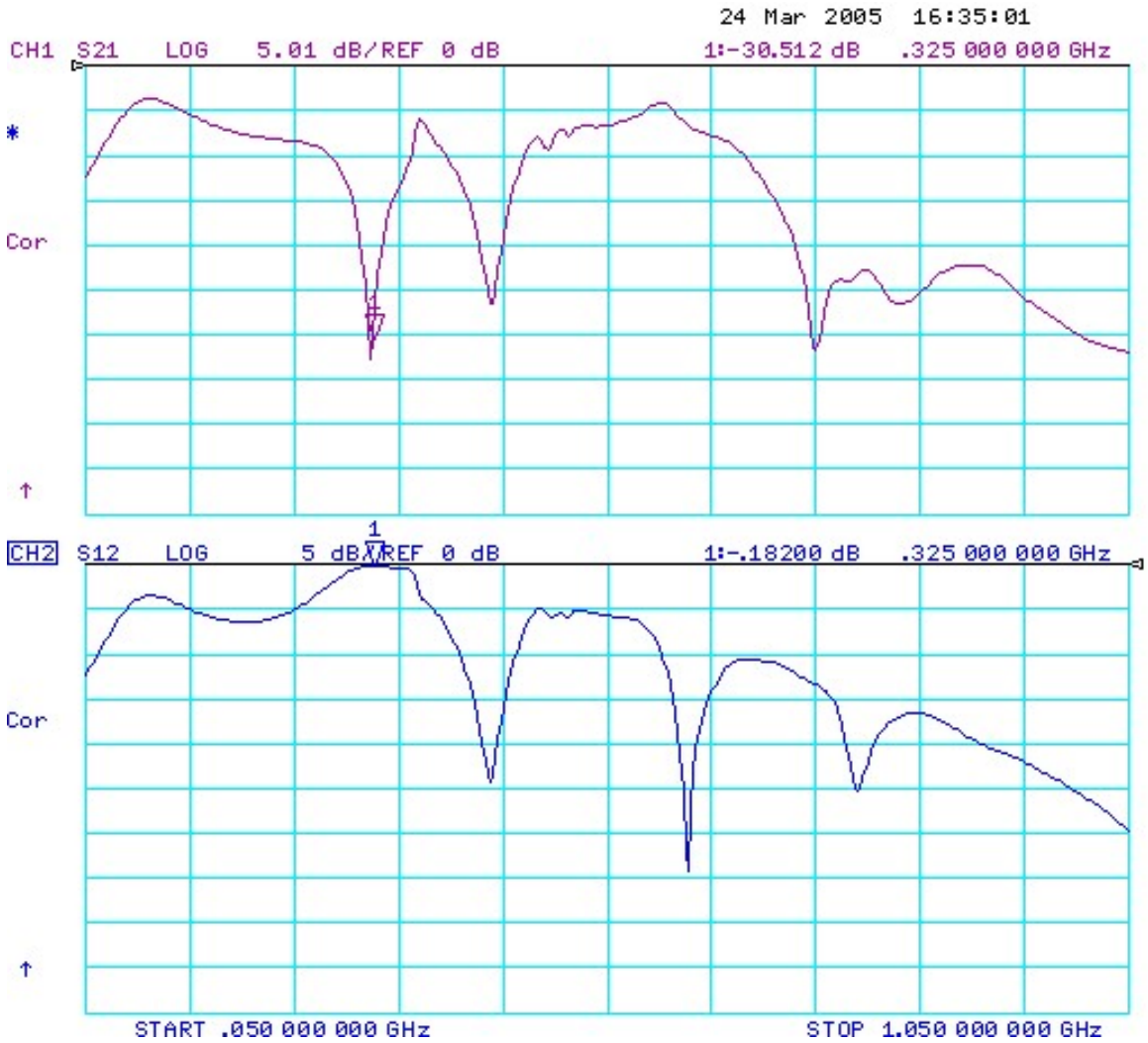
Circulator (status)

- **Stripline Y-junction Type**
- **Prototype (low power): RF part finished, final permanent magnet design to be completed.**
- **A prototype for "high" power test has been designed. 50% of mechanical drawing completed.**





Circulator (measured S parameters)



Isolation: -30 db

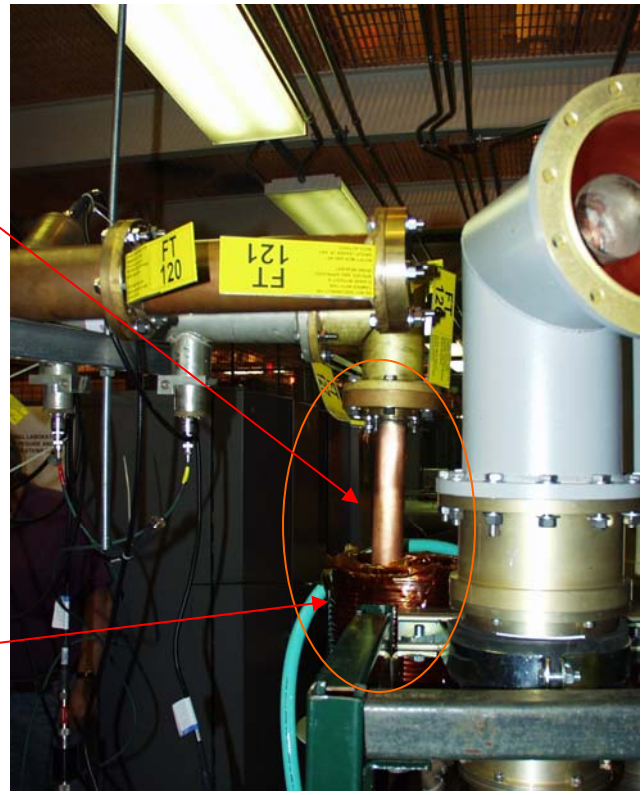
Insertion lose: -0.18 db

Circulator (plan)

- **Fabricate the prototype circulator (2-3 months) and measure it at low power level, modify it if necessary.**
- **High power test to determine:**
  - Power limit for this initial design
  - Thermal effect
- **Increase height for higher power handling capability.**
- **How to compensate thermal effect (cooling control).**
- **Finalize permanent magnet design and mech. detail.**
- **Time: 12 - 24 months.**
- **Cost: $ 20 - 30 k (cooling control not included)**

Phase Shifter

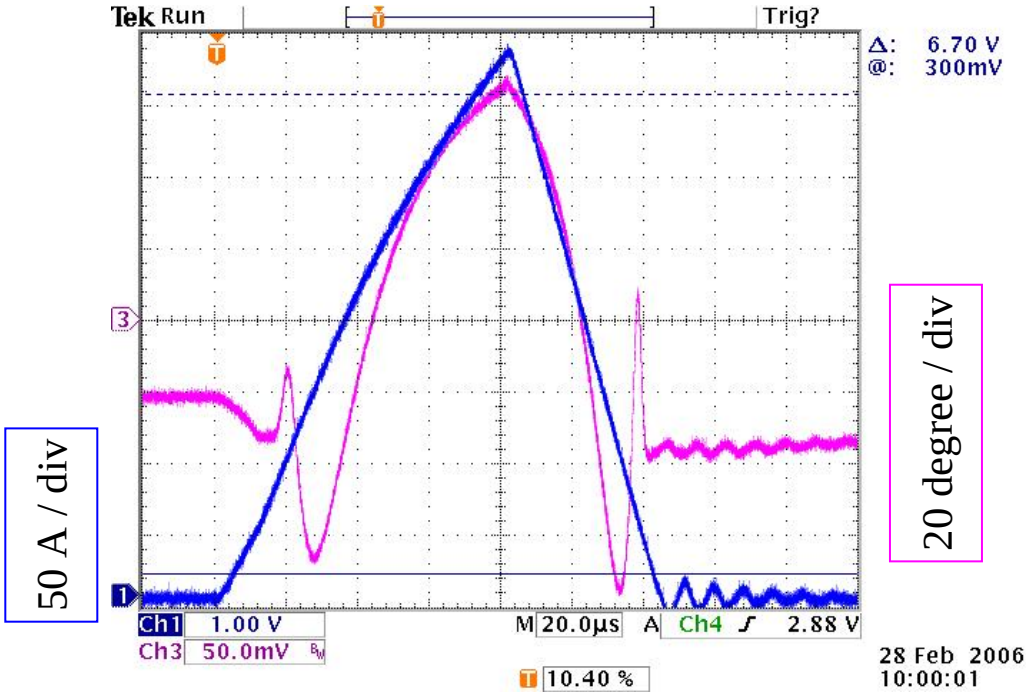
- **Coax line is filled with ferrite material and shorted at end: power is fully reflected.**
- **Effective length of coax line is controlled by magnetic field applied with a solenoid.**



Phase Shifter (Status)

- **High power tested:**
  - 1 5/8” O.D. coax line: 85 kW
  - 3 1/8” O.D. coax line: 440 kW (2.5” long ferrite)
- **Speed of phase change (low power): 120 degree/50 μsec**

Blue: current of solenoid
Purple: phase of output power

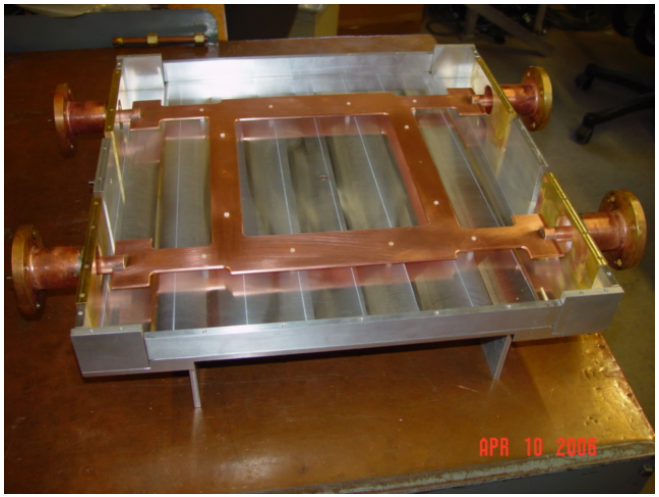


Phase Shifter (plan)

- **Fast phase shift during high power pulse**
- **Measure thermal heating effects at full power**
- **High power test up to 400 kW with 3" O.D. x 5" long garnet**
- **Control phase and amplitude to real cavity**

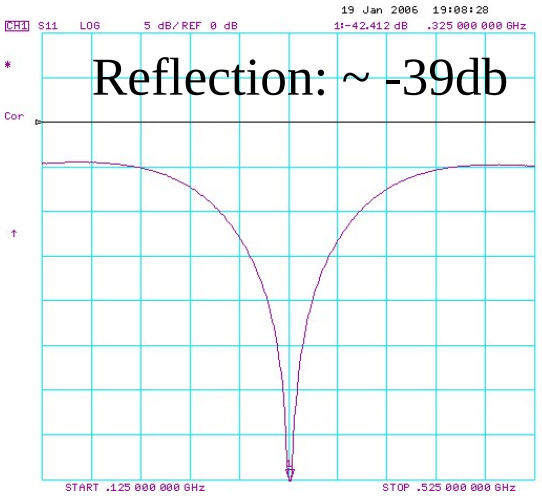
Hybrid

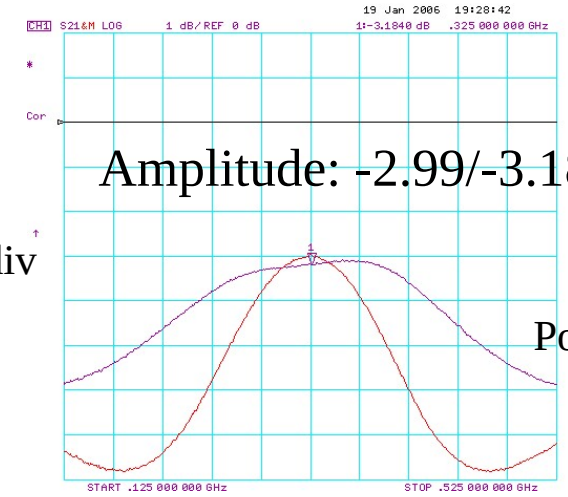
- **A quadrature branch line coupler made of copper sheet with thickness of 0.125”**
- **A matching section at end of each arm for transition of suspended striplines to 1 5/8” coaxial line ports**
- **No cooling**
- **Easy fabrication – low cost**
- **Bandwidth: ~60 MHz**

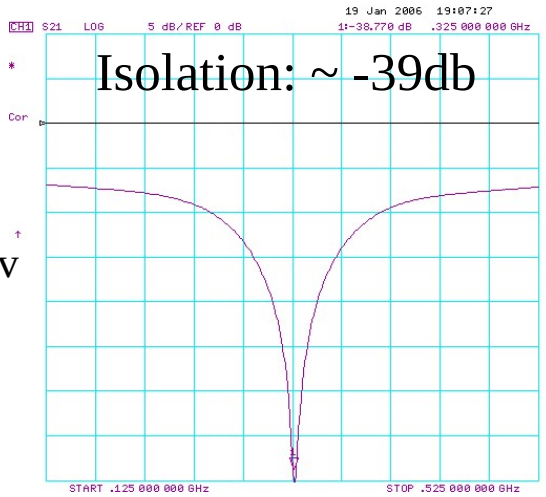


Box: 20” x 20”

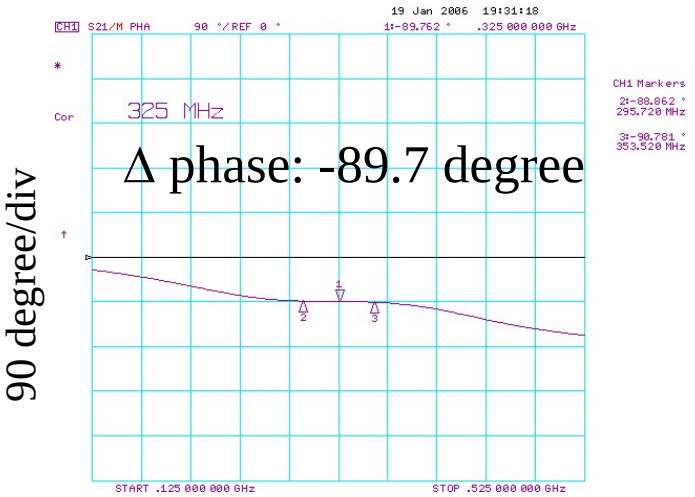
Hybrid (measured S parameters)







Frequency



Frequency

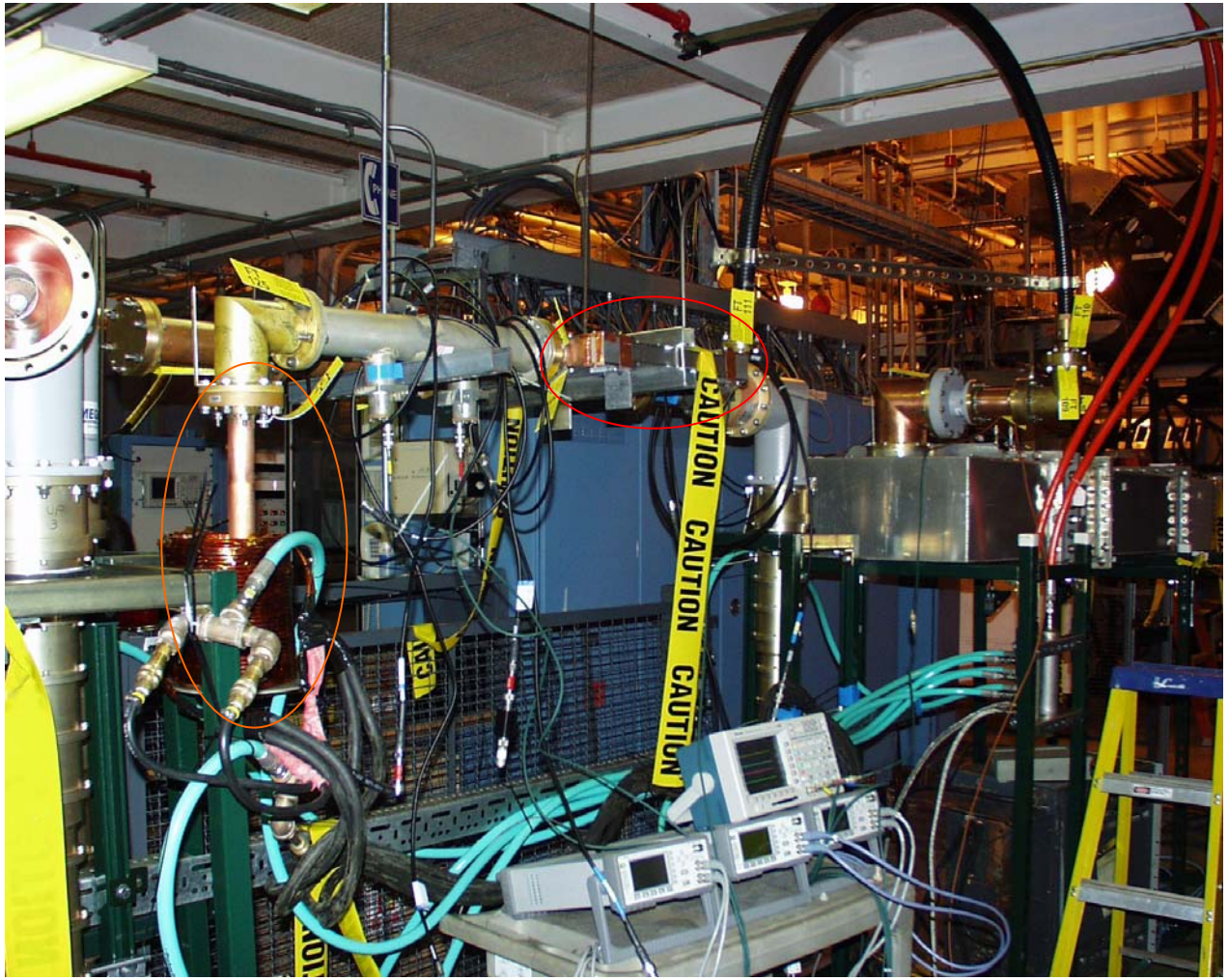
Hybrid (status and plan)

- **Status: high power tested: 170 kW without failure under full reflection condition**
- **Plan:**
  - Add directional coupler within the box for signal processing (cost saving).
  - Further test at FNAL to see power limit using fixed coax line sections with various lengths.
  - Modify design (increase height) for higher power (~ 275 kW for RFQ).

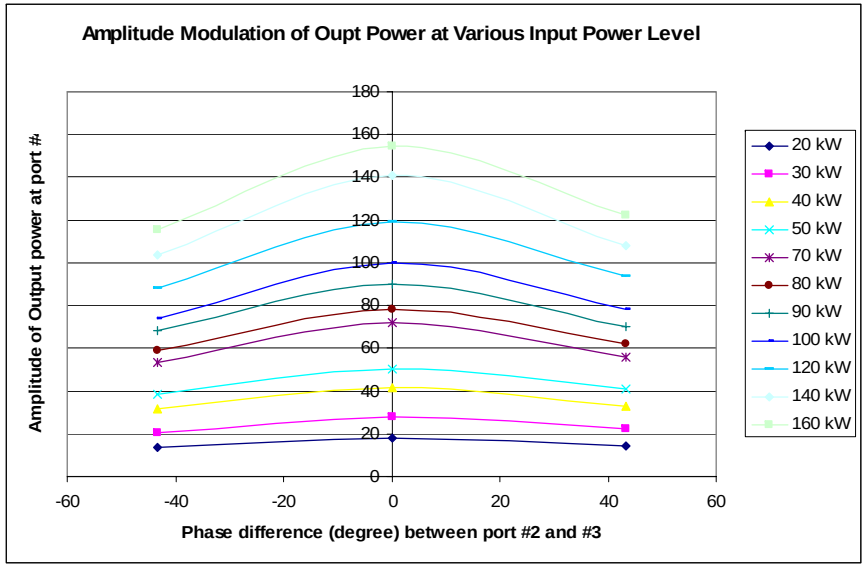
Recent High Power Test Results

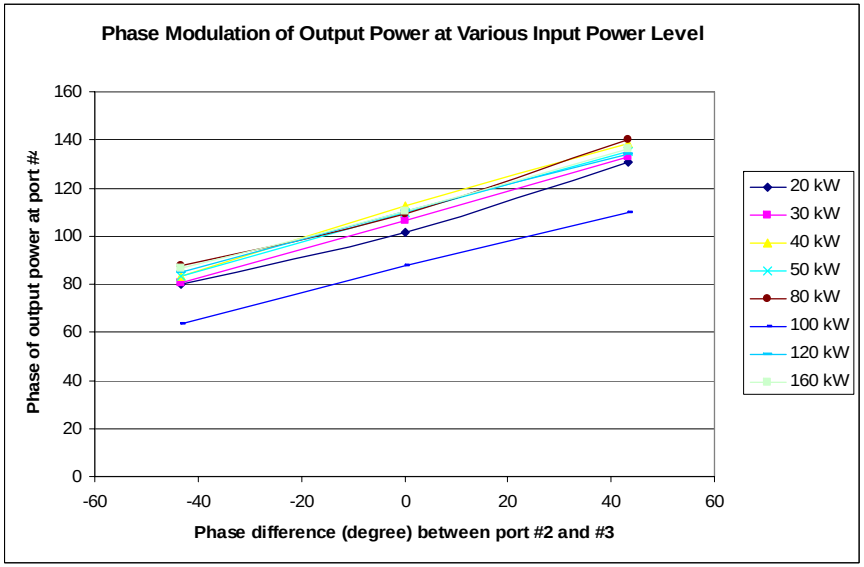
- **A hybrid and a phase shifter together (a partial IQ Modulator) was tested up to 170 kW input power level (limit of 1 5/8” phase shifter).**
- **APS 1.3 MW CW Klystron configured in pulsed mode (pulse length: 4 ms, rep rate:1Hz).**
- **Port #2 is connected with a 1 5/8” ferrite phase shifter, port #3 is shorted.**
- **Amplitude and phase of output power (port #4) was controlled at all power levels by adjusting phase shifter.**

Recent High Power Test (setup)



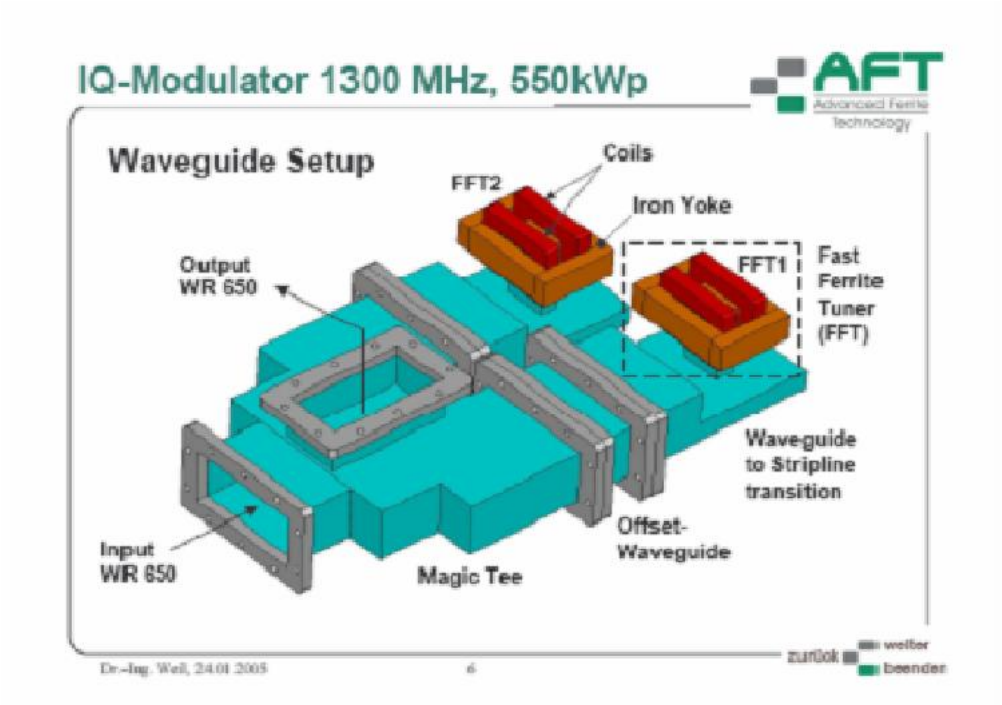
Recent High Power Test Results (plot)





1.3 GHz IQ Modulator

- **For main linac 1.3 GHz superconducting cavities.**
- **Waveguide version will be delivered in July, 2006.**
- **Can be used for ILC.**



Conclusions

- **IQ Modulator R&D are doing well following original plan.**
- **Hybrid and ferrite phase shifter together have been (1) power tested up to 170 kW which exceeds all power requirement of front linac except for RFQ and (2) functioned as IQ modulator at high power levels.**
- **For modest cost so far, IQ Modulator R&D is well worthwhile: enable us to have experience on how to make high power ferrite device work for HINS and possibly ILC.**
- **We have a plan for what to do next to get to a 325 MHz Front End Linac in Meson.**